U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Bird Ingestion Certification Standards	**Date**: 1/19/01	**AC No**: AC 33.76
	Initiated By: ANE-110	**Change**:

1. **PURPOSE.** This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the bird ingestion requirements of § 33.76 of the Federal Aviation Regulations, Title 14 of the Code of Federal Regulations. Although this AC does refer to regulatory requirements that are mandatory, this AC is not, in itself, mandatory. This AC neither changes any regulatory requirements nor authorizes changes in or deviations from the regulatory requirements.

2. **BACKGROUND**.

a. This effort was adopted as a part 33 and Joint Aviation Regulations for engines (JAR-E) harmonization project and was selected as an Aviation Rulemaking Advisory Committee (ARAC) project.

b. This AC provides information and guidance that addresses Federal Aviation Administration (FAA) type certification standards for aircraft turbine engines with regard to bird ingestion. The requirements under § 33.76 reflect recent analysis of the bird threat encountered in service by turbine engine powered aircraft.

3. **DEFINITIONS**. For the purpose of this AC, the following definitions apply:

a. Ingestion. Ingestion is defined as the passage of a bird into the rotating blades of a turbine engine.

b. Front of the Engine. The front of the engine is characterized as any part of the engine that can be struck by a bird. This includes, but is not limited to, the following engine components:

(1) inlet mounted components,

(2) nose cone,

(3) spinner (centerbody) on the fan or compressor rotor,

(4) engine inlet guide vane or frame strut assemblies, and

(5) any engine protection device.

c. Minimum Engine. A minimum engine is defined as a new engine that exhibits the type design's most limiting operating parameter(s), with respect to the prescribed bird ingestion conditions. These operating parameters include, but are not limited to, power or thrust, turbine gaspath temperature, and rotor speed.

d. First Stage Rotating Blades. The term "first stage rotating blades" includes the first of the exposed stages of any fan or compressor rotor which is susceptible to a bird strike or bird ingestion. These first stage rotating blades are considered to be part of the front of the engine, as defined in paragraph (3)(b). This definition encompasses ducted, unducted and aft fan engine designs. In these latter cases, susceptible blading on multiple rotors (e.g., primary and secondary airflow paths) should be considered separately when complying with § 33.76.

e. Critical Impact Parameter (CIP). A parameter used to characterize the state of stress, strain, deflection, twist, or other condition that will result in the maximum impact damage to the engine for the prescribed bird ingestion condition.

f. Inlet Throat Area. The inlet throat area is the installation limitation on projected capture area of the engine inlet nacelle at its minimum inside diameter as established by the applicant.

4. **GENERAL**. The intent of § 33.76 is to require an applicant to demonstrate that the engine is designed and constructed to be structurally and operationally tolerant, to the degree specified, following the defined bird ingestion events.

a. Front of the Engine. The applicant should assess the bird impact to the critical parameters of the components at the front of the engine. For example, the ability of the spinner to withstand a bird impact should be assessed for the most critical parameters of the spinner. This assessment should include bird size, bird velocity, target location, and spinner rotational speed.

b Artificial Birds. Artificial birds or devices which simulate the mass, shape, density, and impact effects of birds, which are adequately validated as equivalent and which are acceptable to the Administrator, may be used for the ingestion tests.

c. Critical Impact Parameter (CIP). The parameter is generally a function of such things as bird mass, bird velocity, fan/rotor speed, impact location, and fan/rotor blade geometry. The state of maximum impact damage to the engine is relative to the ability to meet the criteria of § 33.76. The CIP for most modern turbofan engines is fan blade leading edge stress, although other features or parameters may be more critical as a function of operating conditions or basic design. For turboprop and turbojet engines, a core feature will most likely be the critical consideration. Regardless of engine design, the most limiting parameter should be identified and understood prior to any demonstration, as any unplanned variations in controlling test parameters will be evaluated for the effect on the CIP and § 33.76 requirements.

(1) Example Considerations for Determining the CIP. For turbofan first stage fan blades, increasing the bird velocity or bird mass will alter the slice mass, and could shift the CIP from leading edge stress to some other highly stressed feature of the blade (e.g., blade root). For fan blades with part span shrouds, it may be blade deflection that produces shroud shingling and either thrust loss or a blade fracture that could be limiting. For unshrouded wide chord fan blades, it may be the trailing edge tip of the blade which experiences damage due to an impact induced shock wave traveling through the blade, or the twist of the blade in the dovetail that allows it to impact the trailing blade resulting in trailing blade damage.

(2) CIP Tolerance. For certification tests, the CIP variation should not be greater than 10% due to deviations in any test plan controlling parameter.

d. Critical Test Parameters. In conducting the analysis or component tests, or both, to determine the critical ingestion test parameters, the applicant should consider related experience for the type and size of engine being evaluated, with particular attention to the types and causes of failures in that related experience.

e. Engine Tests. Engine tests should be conducted with a fully operational engine representative of the type design. The normal functioning of any automatic protective or recovery systems not requiring pilot intervention is acceptable (including automatic power lever movement). However, any such automatic systems may be required for dispatch (e.g., Master Minimum Equipment List) if such functions are necessary to meet the requirements of § 33.76. The Applicant may also conduct the test(s) with any automatic systems in a functionally degraded state, if this does not constitute a less severe test.

f. Test Facilities. The object of the test is to cover all the required impact zones. The test facility should be appropriately calibrated to ensure that the controlling parameters defined by the analysis of the critical conditions (e.g., bird speed, aiming locations) are within an acceptable tolerance. This tolerance band should be derived from an analysis of the sensitivity of the critical impact parameter to variations in the controlling parameters. The band should be such that variation in the most critical impact parameter is not more than 10% resulting from any combination of the controlling parameters (See paragraph 4. c. above). Also, certain test facilities and installations may affect or reduce the stability margin of the engine due to airflow distortion attributed to the close proximity of bird gun(s) to the engine inlet. These effects must be identified prior to the test.

g. Turboprop/Turboshaft Engine Tests. If turboprop or turboshaft engines are tested using an alternative load device which could induce different engine response characteristics compared to when the engine is coupled with a propeller or as installed in the aircraft, the interface with the test facility or other aircraft or propeller systems should be monitored during the test. These results should be used for determining how the engine would respond in a representative installation, and for ensuring that the engine would then comply with the requirements in § 33.76.

h. Aircraft/Engine Interface. The Installation Manual required under § 33.5 should describe the engine/aircraft interfaces that could be affected by bird ingestion events. Of particular interest would be dynamic interactions such as auto surge recovery, auto relight, or propeller auto feather.

i. Inlet Throat Area. The Installation Manual required under § 33.5 should identify as an installation limitation the inlet throat area which was used to determine the quantity and

weight of birds for the overall showing of compliance to § 33.76. Section 33.76(a)(2) contains the specific requirement for this installation limitation. The applicant should take care in determining this value with respect to potential future models or installations, which may require a larger number or size of birds or both. Note that the tables of bird quantities and weights within § 33.76 are based on inlet throat area, not the inlet highlight or engine front flange projected areas.

j. Derivative Engines and Major Design Changes. For type certification of derivative engine models or major design changes to existing models, the required engine tests should be performed under the conditions of § 33.76, unless alternative equivalent demonstration evidence acceptable to the Administrator is provided. This substantiation evidence may come from the applicant's experience on engines of comparable size, design, construction, performance, and handling characteristics, obtained during development, certification or operation. Any parametric analysis used as compliance substantiation for type certification or for major design change approval, should fall within a 10% or less variation in the most critical impact parameter(s) identified for the baseline engine certification. The critical impact parameter(s) is often associated with impact load at the point of bird and rotor blade contact. This is generally a function of bird speed, rotor speed, and blade twist angle. This 10% variation (on the critical impact parameter) should not be assumed to be a direct tolerance on the applicants proposed changes to takeoff power or thrust ratings themselves.

k. Hot Day Corner Point Operation. The intent of § 33.76(a)(1) is to demonstrate, to the degree specified, that the engine is designed and manufactured to be structurally and operationally tolerant following bird ingestion conditions when operated at this critical point of the operating envelope. Compliance may include an actual engine test at hot day corner point conditions, or may be based on other representative engine or component tests, validated analysis, representative service events, or any combination of these acceptable to the FAA. Applicants are encouraged to conduct the bird tests at the hot day corner point condition if test facilities allow. Also, tests may be conducted at reasonable levels of power/thrust overboost (e.g., operation at P3 limit) to minimize the use for less direct methods of showing compliance (e.g., analysis), especially if the proposed engine test ambients are less severe then sea-level standard day conditions. If analysis is used to show compliance, it should show the ability to predict bird ingestion event outcomes relative to the requirements and criteria of § 33.76. The analysis approach must be agreed to between the FAA and the applicant, and should be submitted early in the program to avoid impacting program schedules.

SECTION 1

Large Bird Ingestion

5. **GUIDANCE FOR LARGE BIRD INGESTION**.

a. For the purpose of the § 33.76 test, the complete loss of engine power or thrust after ingestion will be accepted.

b. The most critical location on the first stage rotating blades may be determined from analysis or component tests, or both. Determination of the most critical location to be considered should include evidence, where necessary, on:

(1) the effect of the bird strike on rotating components,

(2) the compressor casing strength,

(3) the possibility of multiple blade failures, the strength of the engine structure and main shafts relative to the unbalance and excessive torque likely to occur.

(c) When compliance with the large bird ingestion requirements is proposed to be accomplished under 33.76(b)(4), it should be demonstrated that the test(s) conducted under 33.94(a) constitutes a more severe demonstration of rotor blade containment and rotor unbalance than the large bird ingestion engine test required under 33.76(a)/(b)(1)&(2). This comparative demonstration should consider, but is not limited to, the following results from the required 33.94(a) test(s):

(1) Unbalance loads.

(2) Torque loads.

(3) Surge loads.

(4) Containment capability.

(5) Fire protection capability.

(6) Mound load capability.

Primary engine structure (e.g., rotors, frames, cases, engine/gearbox mounts, etc.) and externally mounted components (e.g., oil tank, heat exchangers, etc.) should be considered when comparing loads between the two events. Unbalance loads could result from rotor material loss or loss of rotor centerline. Torque loads could result from rotor-case interaction or rotor-object impacts. Surge loads could result from engine operating instabilities. Axial loads due to rotor-bird impact should also be considered when comparing the two events. Also, using 33.76(b)(4) as a compliance method is generally predicated on having adequate 33.94(a) test data available, and should focus on predicting the engine dynamic response to a large bird ingestion event relative to the pass/fail criteria of 33.76(b)(3).

(d) The 200 knots ingestion speed for the large bird requirement was selected as the optimum speed to accommodate, within a single demonstration, the various critical impact parameters (CIP) associated with typical turbofan engine designs currently in service. For a specific engine design, however, an applicant may determine that an ingestion speed other than 200 knots is more critical when considering the overall criteria of § 33.76(b). The applicant may apply for an equivalent safety finding under 21.21(b)(1) prior to the conduct of the test, and if approved, use a bird speed other than 200 knots when that speed represents a more conservative or more complete evaluation of the proposed design. Use of that alternate speed must then be noted in the certification basis as an equivalent level of safety finding under § 21.21(b)(1).

SECTION 2

Small and Medium Bird Ingestion

6. **GUIDANCE FOR SMALL AND MEDIUM BIRD INGESTION**.

a. The applicant should identify the critical target locations for the small and medium bird ingestion tests required by § 33.76(c), and consider potential effects of assumed installations in the aircraft. After targeting one bird for the most critical exposed location, the applicant should target any remaining birds in proportion to the fan face area, including the centerbody if applicable, to achieve an even distribution of birds over the face of the engine. The even distribution of remaining birds should also include consideration of any additional critical locations. Any critical locations not targeted may be evaluated separately by analysis or component testing, or both.

b. In the tests performed under § 33.76(c), the engine is required to produce at least 75% of takeoff power or thrust after ingestion of small and medium birds. A momentary power or thrust drop below this value may be acceptable as long as the duration does not exceed 3 seconds.

c. Any analytical means used in place of a test demonstration for evaluating or determining compliance with § 33.76, should be validated by evidence based on representative tests and should have demonstrated its capability to predict engine test results.

d. Rig tests may be used to determine if a particular bird size will pass through the inlet and into the rotor blades.

e. Thrust or power should be measured by a means which can be shown to be accurate throughout the test to enable the thrust or power to be set without undue delay and maintained to within plus or minus 3% of the specified levels. If a sustained high vibration condition exists after the first 2 minutes of operation after the bird ingestion, then thrust or power may be varied as a protective measure within plus or minus 3% of the specified levels. Alternative load devices of some test facilities such as waterbrakes, may be unable to control power within the plus or minus 3% tolerance. This should be identified and approved prior to the test.

f. Exceedences of engine operating limits are not expected to occur. However, exceedences may be permitted to occur only during the first 2 minutes (reference § 33.76(c)(7)(ii)) following the ingestion of the birds in the 20 minute run-on test. Any limit exceedence(s) should be recorded, and it should be shown by evidence acceptable to the Administrator, that the limit exceedence(s) will not result in an unsafe condition (reference § 33.76(c)(10)). This evidence may come from previous test or service experience, or analysis thereof. In addition, under such circumstances, the operating instructions, installation manual, and maintenance manual should be reviewed to assure that appropriate instructions are included within those documents, and that any such instructions are appropriately validated.

/s/
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